AN OVERVIEW OF THE ATLAS PULSED-POWER SYSTEMS

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Abstract

Atlas is a facility being designed at Los Alamos National Laboratory (LANL) to perform high energy-density experiments in support of weapon-physics and basic-research programs. It is designed to be an international user facility, providing experimental opportunities to researchers from national laboratories and academic institutions. For hydrodynamic experiments, it will be capable of achieving pressures exceeding 20-Mbar in a several cm^3 volume. With the development of a suitable opening switch, it will also be capable of producing soft x-rays.

The 36-MJ capacitor bank will consist of 240-kV Marx modules arranged around a central target chamber. The Marx modules will be discharged through vertical triplate transmission lines to a parallel plate collector inside the target chamber. The capacitor bank is designed to deliver a peak current of 45 to 50 MA with a 4- to 5-μs risetime. The Marx modules are designed to be reconfigured to a 480-kV configuration for opening switch development. Predicted performance with a typical load is presented. Descriptions of the major subsystems are also presented.

Introduction

The Atlas project within the High Energy Density Physics Program at Los Alamos is an element of a strategic response to the changing requirements[1] being placed on Department of Energy Defense Programs. Pulsed power machines are used to generate high energy density conditions by discharging multi-megampere currents into a centrally located, cylindrical liner. Near the liner, the current density and associated magnetic fields dramatically increase. The interaction of the current and magnetic field produces Lorentz forces which implode the cylindrical liner. A lightweight liner can collide with itself on axis, converting its kinetic energy into soft x-rays. A heavier liner can be used to either compress sample materials to high density, or when driven into a central target, produce extremely high shock pressures for hydrodynamic experiments. For example, Atlas will be capable of driving ~70-g liners into multi-cm^3 targets, producing shock pressures exceeding 20 Mbar.

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14. ABSTRACT
Atlas is a facility being designed at Los Alamos National Laboratory (LANL) to perform high energy-density experiments in support of weapon-physics and basicresearch programs, It is designed to be an international user facility, providing experimental opportunities to researchers from national laboratories and academic institutions. For hydrodynamic experiments, it will be capable of achieving pressures exceeding 20-Mbar in a several cm3 volume. With the development of a suitable opening switch, it will also be capable of producing soft x-rays. The 36-MJ capacitor bank will consist of 240-kV Marx modules arranged around a central target chamber. The Marx modules will be discharged through vertical triplate transmission lines to a parallel plate collector inside the target chamber. The capacitor bank is designed to deliver a peak current of 45 to 50 MA with a 4- to 5-ps risetime. The Marx modules are designed to be reconfigured to a 480-kV configuration for opening switch development. Predicted performance with a typical load is presented. Descriptions of the major subsystems are also presented.

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System design

To reach the extreme pressures required for hydrodynamic experiments[2], Atlas must be capable of producing a peak current of 45- to 50-MA. The machine must also be flexible in order to accommodate a wide variety of weapons physics and basic research experiments. Other requirements for the facility include: (1) maximizing the radial and axial diagnostic access around the target chamber, (2) a machine reliability of 95% or greater, (3) experimental capability of 100 shots/year, and (4) a machine lifetime of 1000 shots at full voltage. Finally, the facility will include full support services for users including data analysis, film processing, and planning and coordination areas.

Atlas is being designed as a resistively damped machine to limit capacitor voltage reversal and fault currents. This makes possible the use of medium-energy density capacitors such as those used on Pegasus II[3]. It also reduces the risk of switch damage by preventing excessive ringing of the capacitor charge through the spark gaps. A simplified schematic of the Atlas discharge circuit is shown in Fig.1.

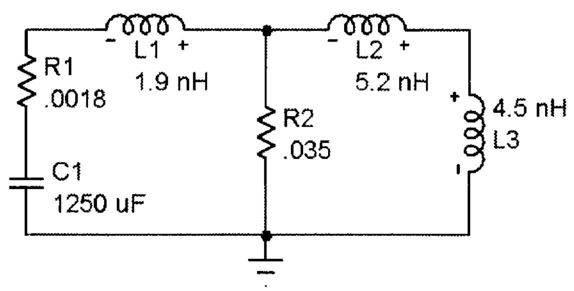

Figure 1. Simplified Atlas schematic

C1 represents the equivalent capacitance of the erected Marx modules at 240 kV. The series resistor, R1, provides the circuit damping. L1 represents the inductance of the erected Marx modules, while L2 is the inductance of the transmission lines and the parallel plate collector. R2 is a shunt damping resistor that prevents parasitic ringing between the transmission line capacitance (not shown) and the Marx module inductance. L3 represents the inductance of the power flow channel and the load. A calculated waveform, showing the current delivered to a 10-cm-diam liner, is illustrated in Fig. 2.

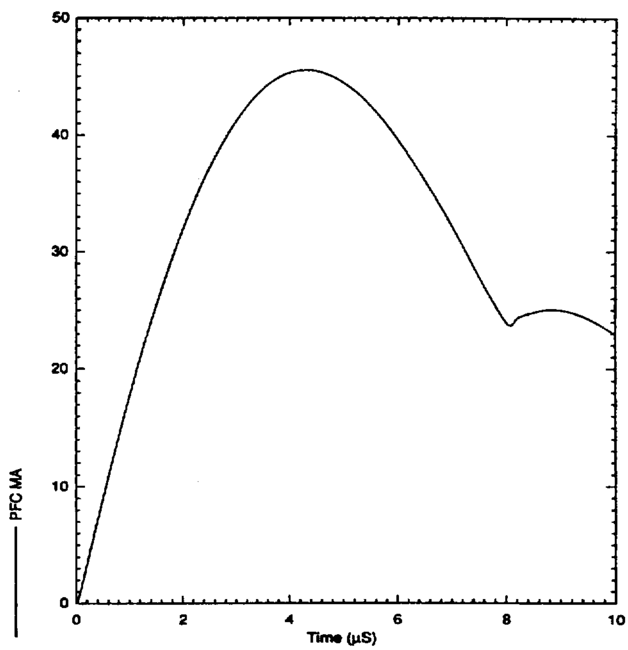

Figure 2. Current (MA) vs time (us) for liner implosion

The 36-MJ Atlas capacitor bank will consist of 152 Marx modules[4] which will be contained in 19 oil tanks arranged in a circular fashion around a centrally-located target area. A total of 38 oil-insulated vertical-triplate transmission lines will carry the Marx module discharge current into a parallel plate collector within the target chamber. Fig. 3 is a CAD rendering of the capacitor bank, transmission lines, and target area.

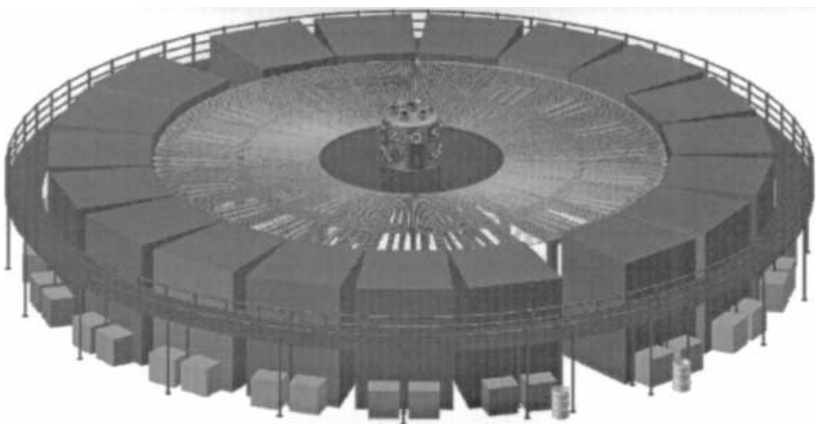

Figure 3. CAD rendering of Atlas

The remainder of the paper will describe the major subsystems that comprise Atlas. These subsystems include the Marx modules, transmission lines, trigger system, charging system, target area, and the controls and data acquisition systems.

Marx modules

Each of the 152 Marx modules contains four, 60-kV, 60-kJ capacitors[5]. Two railgap switches[6] will be used to "erect" each of the Marx modules into its 240-kV configuration. The center capacitors in the Marx module will be interconnected with a stainless steel resistor to provide damping. Fourteen, RG-220 coaxial cables will be used to transmit current from the module to an output header. A physical schematic of a 240-kV Marx module is shown in Fig. 4.

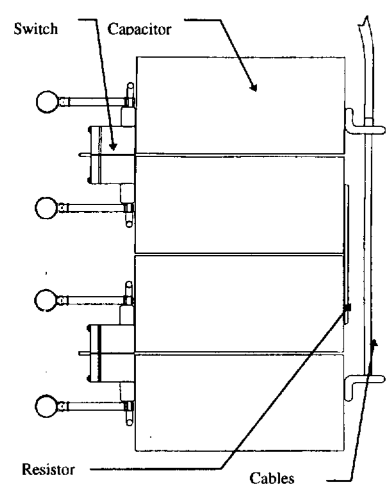

Figure 4. 240-kV Marx module

The 240-kV modules will be arranged in vertical stacks with two modules in each stack. For opening switch development, the two modules can be reconfigured in series to form a single 480-kV Marx module. This will reduce both the rise time of the system and the "closed" state conduction requirements of the switch.

Two stacks of Marx modules will be mounted together to form a "maintenance unit". Each maintenance unit will be independently removable from the system and will contain its own control and data acquisition module, capacitor charging supply, and railgap trigger system. There

will be two maintenance units in a single oil tank. We anticipate that periodic maintenance of the railgaps will require that one maintenance unit will be removed from the system on a weekly basis. A ready spare will immediately take its place. The modularity of the maintenance units will help achieve the maximum anticipated operation of 2 experiments per week while still insuring the overall system reliability requirements.

Transmission lines

Each maintenance unit will be connected to the target area by an oil-insulated, vertical triplate system. These transmission lines must carry 1.3 MA under a normal discharge, withstand a discharge voltage of 220 kV, and introduce minimum inductance to the system.

A transmission line consists of three parallel plates. The center conductor will carry current to the load while the outside plates act as the return. The plates are approximately 2-m tall at the connection point to each maintenance unit. This dimension allows sufficient room for connecting the 56 RG-220 cables in two vertical rows. At the target chamber end, the transmission lines narrow to approximately 0.3-m tall and transition to a horizontal, parallel plate collector. Two sets of transmission lines will be housed in a single oil containment trough attached to each of the 19 oil tanks.

Each transmission line will have an output shorting switch located near the connection to the oil tank. During charging, these switches will remain closed. When the bank reaches full charge, they will open in approximately 100 ms. The bank will then be immediately triggered. The output shorting switch provides three functions. First, it protects the load assembly from current in the case of a Marx module prefire. Second, these switches allow the flexibility to discharge the modules, individual or collectively, without subjecting the load region to significant voltage or current. This technique could be used to condition components and test for faults without affecting the center of the machine. Third, this normally-closed switch provides an additional safety system to protect personnel from any residual voltage on the capacitors while they are working in the center of the machine.

Trigger system

Triggering for the railgaps will be provided by an independent trigger system located in each maintenance unit. Each trigger system will have 8 output cables which connect to the 8 railgaps in the maintenance unit. The trigger system itself will be triggered by a fiber-optic pulse generated by the master controller. Several commercially available models are currently being evaluated, including the PSI unit shown in Fig. 5.

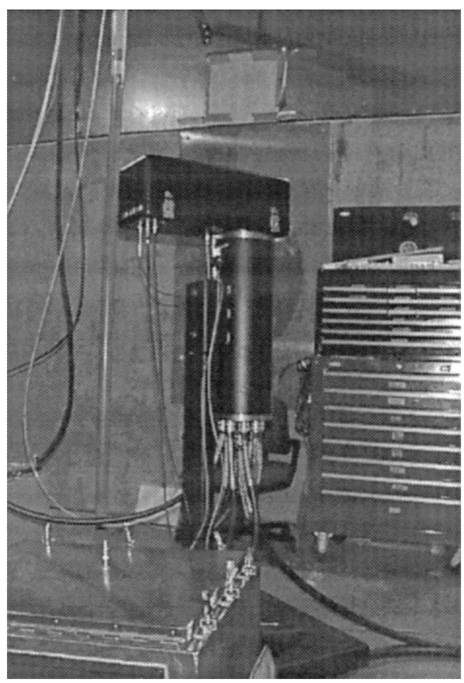

Figure 5. PSI trigger system

To initiate a multichannel discharge in each of the railgaps, the output trigger pulse must have a rate of voltage rise (dV/dt) of approximately 10 kV/ns and an open-circuit voltage of 100 kV. Because each trigger system will have its own throughput delay, differences will be equalized by individual time delay generators connected to each of the optical trigger generators. Once the delays are equalized, there will still be small statistical time differences among the 38 trigger systems. System jitter is expected to be in the range of 10 to 20 ns, typical of commercially available units.

It is important that the trigger system itself not contribute appreciably to the system prefire rate. To avoid impacting the system reliability, it is necessary for each of the 38 individual trigger systems to have a prefire/nofire rate of less than 1 shot in 8000. This requirement may mandate additional refinements to the present commercial units under evaluation.

Capacitor bank charging system

The minimum required charging time of the capacitor bank is 24 seconds. A highly-reliable system will be achieved by using parallel-connected, modular charging supplies. Each supply will be rated for 10 kJ/s. There will be two positive and two negative supplies for each maintenance unit, for a total of 152 supplies in the complete system. These supplies are available from a large number of manufacturers and have proven track records in magnetic fusion and accelerator facilities. Additionally, each supply can act as a master supply, controlling the three other supplies in each maintenance unit, or act as a slave. Specifications for the supplies are listed in Table I.

Table I. Power Supply Specifications

Output charge rate (kJ/s)	10
Output voltage (kV)	±65
Voltage regulation (%)	≤ ±0.1
Input voltage (VAC)	480, 3ϕ wye
Input current (A)	≤ 30
Power factor	≥ 0.9
Duty factor (%)	25
Controls	Master/slave

Target area

Present estimates indicate more than 12-MJ of energy will be trapped and dissipated in the target chamber[7] during a normal experiment. The current design of the target chamber has walls that are lined with energy absorbing material to prevent damage from the shrapnel and debris of the discharge. The chamber will be approximately 2 m in diameter to support an extensive suite of diagnostics.

Because of the variety of anticipated experiments, a high degree of flexible diagnostic access is necessary. Diagnostic access for end-on and radial views of the target will be available. Several in-line port pairs for diagnostics that involve active backlighting with visible light or x-rays will

also be available. The large chamber dimensions necessitate re-entrant port capability for those diagnostics that require close proximity to the load. To facilitate alignment of these diagnostics, the target chamber and associated diagnostics will be preassembled in a staging area, and then lowered onto the machine for final alignment.

Controls, diagnostics and data acquisition

Attached to each of the 38 maintenance modules will be a control and monitoring station[8]. This station will control the charging, dump, and isolation switches, and will monitor voltage, current, gas pressure and flow in the railgaps, and the trigger timing. During the charge cycle, the station will control the power supplies while monitoring the charge current and voltages to detect fault conditions. If a fault is detected, each control station will have the ability to shut down its power supply and notify the rest of the system to initiate a shutdown-on-fault sequence.

The master data acquisition system will acquire and archive the data from both the machine and user-provided diagnostics. The master diagnostic system will provide a reasonable degree of freedom for experimenters to record their data the way they want, while at the same time enforcing a uniform and efficient approach to making the experimental data available to other users.

In addition to data recording equipment, the data acquisition system will include several workstations to interface with the recording equipment, appropriate fiber-optic network connections between the workstations and the recording equipment, and a powerful database server running a high-end database management system to store the data.

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